

1 In the claims:

2 1. A method for gamut mapping of an input image using a space varying →  
3 algorithm, comprising:

4 receiving the input image;

5 converting color representations of an image pixel set to produce a corresponding  
6 electrical values set;

7 applying the space varying algorithm to the electrical values set to produce a  
8 color-mapped value set; and

9 reconverting the color-mapped value set to an output image.

10 2. The method of claim 1, wherein the space varying algorithm minimizes a  
11 variational problem represented by:

12 
$$E(u) = \int_{\Omega} (D^2 + \alpha |\nabla D|^2) d\Omega, \text{ subject to } u \in \mathcal{G}, \text{ wherein } \Omega \text{ is a support of the input}$$

13 image,  $\alpha$  is a non-negative real number,  $D = g^*(u - u_0)$ ,  $g$  is a normalized Gaussian kernel  
14 with zero mean and a small variance  $\sigma$ ,  $u_0$  is the input image, and  $u$  is the output image.

15 3. The method of claim 2, further comprising:

16 solving the variational problem at a high value of  $\alpha$ ;

17 solving the variational problem at a low value of  $\alpha$ ; and

18 averaging the solutions.

19 4. The method of claim 3, wherein the step of averaging the solutions comprises  
20 using a spatially adaptive weighting scheme, comprising:

$$u_{final}[k, j] = w[k, j]u_{small}[k, j](1 - w[k, j])u_{high}[k, j]$$

21 wherein the weight  $w[k, j]$ , comprises:

$$w[k, j] = \frac{1}{1 + \beta |\nabla g * u_0|^2}, \text{ and}$$

22 wherein  $\beta$  is a non-negative real number.

23 5. The method of claim 2, wherein the variational problem is solved according to:

$$\frac{du}{dt} = \alpha g * \Delta D - g * D, \text{ subject to } u \in \mathcal{G}.$$

24 6. The method of claim 2, wherein the space varying algorithm is solved according  
25 to:

1  $u_{ij}^{n+1} = u_{ij}^n + \tau(\alpha L_{ij}^n - \bar{D}_{ij}^n)$ , subject to  $u_{ij}^n \in \mathcal{G}$ , wherein

2  $\tau = dt$ ,

2  $\bar{D}^n = g * g * (u^n - u_0)$

2  $L^n = D_2 * (u^n - u_0)$  and

2  $D_2 = g_x * g_x + g_y * g_y$

3 7. The method of claim 1, wherein the space varying algorithm minimizes a  
4 variational problem represented by:

5  $E(u) = \int_{\Omega} (\rho_1(D) + \alpha \rho_2(|\nabla D|)) d\Omega$ , subject to  $u \in \mathcal{G}$ , wherein  $\rho_1$  and  $\rho_2$  are scalar  
6 functions.

7 8. The method of claim 2, further comprising:

8 decimating the input image to create one or more resolution layers, wherein the  
9 one or more resolution layers comprises an image pyramid; and

10 solving the variational problem for each of the one or more resolution layers.

11 9. The method of claim 1, wherein the method is executed in a camera.

12 10. ~~The method of claim 1, wherein the method is executed in a printer.~~

13 11. A method for color gamut mapping, comprising:

14 converting first colorimetric values of an input image to second colorimetric  
15 values of an output device, wherein output values are constrained within a gamut of the  
16 output device; and

17 using a space varying algorithm that solves an image difference problem.

18 12. A computer-readable memory for color gamut mapping, comprising an instruction  
19 set for executing color gamut mapping steps, the steps, comprising:

20 converting first colorimetric values of an original image to second colorimetric  
21 values, wherein output values are constrained within a gamut of the output device; using a  
22 space varying algorithm that solves an image difference problem; and

23 optimizing a solution to the image difference problem.

24 13. ~~The computer-readable memory of claim 12, wherein the image difference~~  
25 ~~problem is represented by:~~

26  $E(u) = \int_{\Omega} (D^2 + \alpha |\nabla D|^2) d\Omega$

1 subject to  $u \in \Omega$ , wherein  $\Omega$  is a support of an input image,  $\alpha$  is a non-negative real  
2 number,  $D = g^*(u - u_0)$ ,  $g$  is a normalized Gaussian kernel with zero mean and small  
3 variance  $\sigma$ ,  $u_0$  is the input image, and  $u$  is an output image.

4 14. The computer-readable memory of claim 12, wherein the instruction set further  
5 comprises steps for:

6 solving the image difference problem at a high value of  $\alpha$ ;  
7 solving the image difference problem at a low value of  $\alpha$ ; and  
8 averaging the solutions.

9 15. The computer-readable memory of claim 14, wherein averaging the solutions  
10 comprises using a spatially adaptive weighting scheme, comprising:

$$u_{final}[k, j] = w[k, j]u_{small}[k, j](1 - w[k, j])u_{high}[k, j] \text{ and}$$

11 wherein the weight  $w[k, j]$ , comprises:

$$w[k, j] = \frac{1}{1 + \beta |\nabla g * u_0|^2}, \text{ and}$$

13 wherein  $\beta$  is a non-negative real number.

14 16. The computer-readable memory of claim 12, wherein the image difference  
15 problem is represented by:

$$E(u) = \iint_{\Omega} (\rho_1(D) + \alpha \rho_2(|\nabla D|)) d\Omega, \text{ wherein } \rho_1 \text{ and } \rho_2 \text{ are scalar functions.}$$

17 17. The computer-readable memory of claim 12, wherein the instruction set further  
18 comprises steps for:

19 decimating the input image to create one or more resolution layers, wherein the  
20 one or more resolution layers comprise an image pyramid; and  
21 solving the image difference problem for each of the one or more resolution  
22 layers.

23 18. The computer-readable memory of claim 17, wherein the instruction set further  
24 comprises steps for:

25 (a) initializing a first resolution layer;  
26 (b) calculating a gradient  $G$  for the resolution layer, the gradient  $G$  comprising:

1  $G = \Delta(u - u_o) + \alpha_k(u - u_o)$ , wherein  $\Delta x$  is a convolution of each color

2 plane of  $x$  with  $K_{LAP} = \begin{bmatrix} 0 & 1 & 0 \\ 1 & -2 & 1 \\ 0 & 1 & 0 \end{bmatrix}$  and  $\alpha_k = \alpha_o * 2^{2(k-1)}$ ;

3 (c) calculating a normalized steepest descent value  $L_j = L_{j-1} - \mu_o * \mu_{NSD} * G$ , wherein  
4  $\mu_o$  is a constant;

5 (d) projecting the value onto constraints  $\text{Proj}_9(L_j)$ , wherein  $\text{Proj}_9(x)$  is a projection  
6 of  $x$  into a gamut  $9$ ; and

7 (e) for a subsequent resolution layer, repeating steps (b) – (d).

8 19. A method for image enhancement using gamut mapping, comprising:  
9 receiving a input image;

10 from the input image, constructing an image pyramid having a plurality of  
11 resolution layers;

12 processing each resolution layer, wherein the processing includes completing a  
13 gradient iteration, by:

14 calculating a gradient  $G$ ;  
15 completing a gradient descent iteration; and  
16 projecting the completed gradient descent iteration onto constraints; and  
17 computing an output image using the processed resolution layers.

18 20. The method of claim 19, wherein the gradient  $G$ , comprises:

19 
$$G = \Delta(u - u_o) + \alpha_k(u - u_o),$$

20 wherein  $u$  is the output image,  $u_o$  is the input image, and  $\alpha$  is a non-negative real  
21 number.

22 21. The method of claim 19, wherein completing the gradient descent iteration  
23 comprises calculating:

24 
$$\mu_{NSD} = \frac{\Sigma G^2}{(\Sigma(G * \Delta G) + \alpha_k \Sigma G^2)}; \text{ and}$$

25 
$$L_j = L_{j-1} - \mu_o \cdot \mu_{NSD} \cdot G,$$

26 wherein  $\mu_{NSD}$  is a normalized steepest descent parameter,  $\mu_o$  is a constant,  $k$  is a number  
27 of resolution layers in the image pyramid, and  $j$  is a specific resolution layer.

28 22. The method of claim 19, wherein projecting the completed gradient descent  
29 iteration onto the constraints is given by:

1  $\sim L_j = \text{Proj}_g(L_j),$

2 wherein  $\text{Proj}_g(x)$  is a projection of  $x$  into a gamut  $g$ .

3 23. The method of claim 19, wherein constructing the image pyramid, comprises:

4 smoothing the input image with a Gaussian kernel;

5 decimating the input image; and

6 setting initial conductive  $L_0 = \max\{S_p\}$ , wherein  $S_p$  is an image with the coarsest  
7 resolution layer for the image pyramid.

8 24. The method of claim 23, wherein the Gaussian kernel, comprises:

9 
$$K_{PYR} = \begin{bmatrix} \frac{1}{16} & \frac{1}{8} & \frac{1}{16} \\ \frac{1}{8} & \frac{1}{4} & \frac{1}{8} \\ \frac{1}{16} & \frac{1}{8} & \frac{1}{16} \end{bmatrix}$$

10 25. The method of claim 19, wherein processing each resolution layer further  
11 comprises applying a space varying algorithm to minimize a variational problem  
12 represented by:

13 
$$E(u) = \int_{\Omega} (D^2 + \alpha |\nabla D|^2) d\Omega, \text{ subject to } u \in \mathcal{G}, \text{ wherein } \Omega \text{ is a support of the}$$
  
14 image, and  $D = g^*(u - u_0)$ , wherein  $g$  is a normalized Gaussian kernel with zero mean and  
15 small variance  $\sigma$ ,  $u_0$  is the input image,  $u$  is the output image, and wherein  $\alpha$  is a non-  
16 negative real number.

17 26. The method of claim 19, wherein processing each resolution layer comprises  
18 applying a space varying algorithm to minimize a variational problem represented by:

19 
$$E(u) = \int_{\Omega} (\rho_1(D) + \alpha \rho_2(|\nabla D|)) d\Omega, \text{ subject to } u \in \mathcal{G}, \text{ wherein } \rho_1 \text{ and } \rho_2$$
  
20 are scalar functions.

21 27. The method of claim 26, wherein  $\rho_1$  and  $\rho_2$  are chosen from the group  
22 comprising  $\rho(x) = |x|$  and  $\rho(x) = \sqrt{1 + x^2}$ .